2. HEPA FILTER INFRASTRUCTURE

The program for producing high-quality HEPA filters and fabricating the filter banks used in nuclear installations has evolved during the past 50 years. This evolution has involved many interrelated assumptions associated with materials, specifications, testing, and use (Burchsted et al., 1976; Frethold et al., July 14, 1997; Johnson et al., 1988; First, 1996).

As the name suggests, HEPA filters are high-efficiency air filters designed to remove extremely fine particles suspended in the air; they do not remove gases. HEPA filters are expendable, extended-pleated-medium, dry-type filters with (1) a rigid casing enclosing the full depth of the pleats; (2) a minimum particle removal efficiency of 99.97 percent of thermally generated dioctalphthalate (DOP) 0.3 micron smoke particles (particles about one- third of one-thousandth of a millimeter in diameter) or larger (i.e., 99.97 percent of these particles are stopped by the filter); and (3) at a maximum a pressure drop of 1 inch of water gauge when clean and operated at rated airflow capacity (Burchsted et al., 1976). Such filters offer a high-volume, high-efficiency cleanup mechanism for relatively low concentrations of airborne particulate contaminants.

Safety analyses for confinement systems using HEPA filters routinely take credit for reductions in airborne contamination by factors of thousands to billions. These reduction factors are reasonable for intact filters installed in well-designed and well-constructed filter banks that are properly maintained. These conditions are difficult to attain, however, partly because of the fragile nature of the filter medium. A very few small holes in the filter medium (on the order of 1–10 mm in diameter) can reduce filter efficiency significantly.

HEPA filters are manufactured by a process similar to that used for making paper, but with fiberglass strands as the principal ingredient. After the medium is formed into a sheet similar in appearance and texture to a large desk blotter, it is carefully folded into a series of accordion pleats (125 pleats in the most widely used standard industrial HEPA filter). The folded medium is then mounted with the edges sealed in a plywood or metal case. This constitutes a single HEPA filter unit. Dozens or even hundreds of such units may be installed in a single confinement filter installation.

2.1 ACHIEVING INITIAL PRODUCT QUALITY

2.1.1 Specifications

HEPA filters are produced with a high degree of quality and uniformity through the application of stringent yet manageable specifications. The foundation for HEPA quality includes sample specifications found in the 1976 Nuclear Air Cleaning Handbook (Burchsted et al., 1976), issued by the Energy Research and Development Administration, and more recently in DOE Standard 3020-97 (DOE-STD-3020-97), *Specification for HEPA Filters Used by DOE Contractors* (U.S. Department of Energy, 1997), together with the numerous standards they cite and the QPL and Filter Test Facility (FTF) testing they call for. Nevertheless, there are ongoing

technical issues associated with each of these building blocks that have serious implications for maintaining the quality of the filters.

The current version of the Nuclear Air Cleaning Handbook is more than 20 years old. In the intervening years, several unsuccessful attempts have been made to revise and update the handbook, primarily to accommodate numerous changes in applicable national standards. In 1996, the Secretary of Energy made a commitment to the Board (O'Leary, March 15, 1996) to have a revised draft available by the end of that year. That draft has not yet been produced, nor are there any indications that a revised handbook may emerge in the near future.

2.1.2 Filter Testing

Both the Nuclear Air Cleaning Handbook and DOE-STD-3020-97 call for manufacturers to retain their QPL[1] listings. This mandate includes, among other requirements, providing representative sample filter units to an independent, certified QPL laboratory for destructive testing at least once every 5 years.

In the past, manufacturers could choose to have their QPL testing done at either the Army's Edgewood Arsenal or the Rocky Flats Environmental Technology Site (RFETS). Today, the Edgewood Arsenal facility no longer performs QPL testing, and the test facility at RFETS is closed. Edgewood Arsenal still has the capability to run such tests, but there is no budget for maintenance of the necessary equipment. During 1997, the QPL test equipment at RFETS was sent to Lawrence Livermore National Laboratory (LLNL), where most of it remains—still crated and unfunded. The Assistant Secretary of Energy for Environmental Management informed the Board in writing (Alm, January 15, 1998) that a QPL testing laboratory would be available for testing of HEPA filters to be used in DOE facilities. No time frame was specified for that commitment, and such a laboratory has not yet been designated.

In addition to QPL testing, both the handbook and DOE-STD-3020-97 call for representative filters to be provided routinely to a designated FTF for the purpose of verifying filter efficiency. The current DOE standard recognizes that manufacturers may themselves conduct tests similar to those performed at a designated FTF. Even in such cases, however, the standard requires that all filters destined for use in DOE facilities be tested at an independent FTF prior to installation.

For years, manufacturers routinely pretested their HEPA filters before sending them to a DOE FTF. Even with this pretesting, rejection rates of 3–6 percent were common at DOE's three FTFs. Such rejection rates support the value of testing at a DOE FTF, since the tests help avoid the unnecessary generation of contaminated waste and contribute to lowering personnel exposure. This avoidance comes about because the filters that fail the FTF tests are not installed, as they would have been in the absence of the tests; thus the need to remove substandard filters contaminated in service is avoided.

[1] Products on QPLs have met stringent requirements for quality and reliability, demonstrated by periodic independent testing at certified testing laboratories, most of which are operated by the federal government.

Currently, DOE operates only one FTF (at Oak Ridge). Despite the DOE-STD-3020-97 specification calling for FTF testing of HEPA filters prior to installation in DOE facilities, and in the face of DOE's own studies (Lytle, August 1996), there have been repeated proposals to stop testing of filters at the Oak Ridge FTF. Indeed, testing there was stopped in January 1999, but was resumed 2 months later with user fees being imposed for tests. This situation tends to discourage FTF usage and increase per-filter test costs. Ongoing attempts to find a programmatic solution have thus far been unsuccessful.

2.2 MAINTAINING PERFORMANCE

HEPA filters cannot simply be installed and forgotten. Once installed in safety systems, they are subject to significant operating constraints to ensure the desired level of performance. Typically, these constraints involve TSRs and/or OSRs (U.S. Department of Energy, April 30, 1992) that specify a maximum pressure drop for system operation and a level of efficiency as demonstrated by periodic in-place leakage tests. Operating procedures, specific surveillance actions, and scheduled maintenance are usually prescribed to ensure that these performance requirements are met.

Industry consensus standards for in-place HEPA filter testing stress the need for visual inspections and system-specific procedures (American Society of Mechanical Engineers, December 15, 1989). Although specific procedures addressing filter operation are required by industry standards, they are typically lacking throughout the defense nuclear complex (Conway, January 30, 1998) and have not been made mandatory by DOE. These procedures are important for ensuring the safety of workers, the public, and the environment. Only the Savannah River Site has employed them extensively.

For most other systems and components, meeting TSRs ensures that a constrained or challenged item will perform its intended function as called for by the design. This assumption is not valid when nondestructive in-place field tests address only the tightness of the filter's fit against the frame and the absence of other gross leakage paths. There is a widespread assumption that periodic in-place DOP field testing demonstrates the ability of a HEPA filter to perform under accident conditions. Yet, experience has shown that filters can be severely weakened and still successfully pass these in-place tests (Frethold et al., July 14, 1997; Johnson et al., 1988; First, 1996). Under accident conditions, such filters are vulnerable to subsequent failure in use, for example, after becoming heavily loaded with smoke particles.

The question of whether a HEPA filter will perform as intended in the future cannot be answered simply by examining adherence to existing TSRs. Filter performance does not lend itself to a simple "go-no go" test. With today's technology, that assurance is available only through a reliable and effective infrastructure that addresses all aspects of HEPA filter quality—design, manufacture, installation, operation, and maintenance.

2.3 CHALLENGES

2.3.1 Fires

The largest potential threat to the public from a facility that houses processes in which relatively large quantities of radioactive materials are handled is most commonly a fire accident scenario. Since fires often generate large volumes of smoke, they pose a potential threat to the effective functioning of filtration systems because the filters can become rapidly loaded with smoke particles. This increases the pressure drop across the filter, potentially leading to a breach of confinement. There are times during some fire scenarios when it may be necessary to stop flow to the filter systems to prevent their destruction. Such scenarios need to be carefully evaluated ahead of time; a mitigating strategy must be developed, clearly captured in procedures, and rigorously practiced (Defense Nuclear Facilities Safety Board, March 20, 1995; Conway, January 30, 1998; Klein, April 24, 1998).

In the event of a breakthrough of the filter during a fire, the particulate material deposited on the filters is readily lifted by buoyancy into the atmosphere, where it can be further dispersed in potentially unfavorable downwind patterns. As a result, some fires can be more serious than explosions, which generally drive much of the particulate matter into surrounding structures rather than elevating it into the atmosphere and dispersing it via prevailing winds.

2.3.2 Heat and Elevated Temperatures

Because of their materials of construction, HEPA filter installations can easily be damaged or destroyed by heat if they are not properly designed and maintained. Exposure of the filter medium to temperatures of 700–750°F for only 5 minutes can significantly reduce filter efficiency (Burchsted et al., 1976). Fires involving burning metals, which may be encountered in many defense nuclear facilities, can produce flame temperatures of several thousand degrees. With sufficient flow of cooler air, these high temperatures can be reduced to acceptable levels in the downstream HEPA filters. If this cooling effect is to be provided, however, detailed plans and designs are essential. Such plans and designs in turn require appropriate guidance.

In this connection, DOE Handbook 3010 (DOE-HDBK-3010-94) (U.S. Department of Energy, December 1994) implies that HEPA filters can withstand temperatures substantially greater than 1500° F for tens of minutes without losing their nominal efficiency of 99.97 percent. This is not correct, since fiberglass will melt before reaching such temperatures. This erroneous information was used in a recent Basis for Interim Operation (U.S. Department of Energy, April 1998) in which a filter efficiency of 99.8 plus percent was assumed in calculating dose assessments. In this instance, recalculation determined that the temperature likely to be encountered at that facility would not have reached 750°F. However, the same error (i.e., the assumption of no filter damage and filter availability for dose reduction) could recur if the handbook is not revised.

2.3.3 Wetting

Like paper, HEPA filter medium is especially susceptible to water damage, despite the fact that water repellents are applied to the medium during manufacture. When installed fire suppression systems are activated to protect systems, structures, and components inside